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WILLIAMS'

UNIVERSAL TRAVERSE TABLE,

WITH

EXPLANATIONS AND ILLUSTRATIONS;

BY THE

AID OF WHICH ANY PERSON ACQUAINTED WITH COMMON DECIMALS, MAY CALCULATE HEIGHTS, DISTANCES, ALTITUDES, ELEVATIONS, AND RIGHT-ANGLED TRIANGLES GENERALLY.

BY JNO. S. WILLIAMS.

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STEREOTYPED BY J. A. JAMES.....CINCINNATI.

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WILLIAMS'S UNIVERSAL TRAVERSE TABLE, WITH EXPLANATIONS AND ILLUSTRATIONS;

By the aid of which any person, acquainted with common decimals, may calculate heights distances, altitudes, elevations, and right angled triangles generally.

Deg.	Even degrees.		
	Latitude.	Depart.	
1	.999849	.017451	89
2	.999391	.034899	88
3	.998627	.052336	87
4	.997564	.069757	86
5	.996199	.087156	85
6	.994520	.104529	84
7	.992543	.121861	83
8	.990268	.139173	82
9	.987689	.156434	81
10	.984807	.173648	80
11	.981627	.190809	79
12	.978148	.207912	78
13	.974369	.224951	77
14	.970296	.241922	76
15	.965927	.258819	75
16	.961262	.275637	74
17	.956304	.292372	73
18	.951054	.309017	72
19	.945517	.325568	71
20	.939693	.342020	70
21	.933560	.358368	69
22	.927183	.374606	68
23	.920504	.390733	67
24	.913544	.406736	66
25	.906308	.422618	65
26	.898773	.438366	64
27	.891006	.453991	63
28	.882947	.469471	62
29	.874650	.484809	61
30	.866026	.500000	60
31	.857171	.515038	59
32	.848047	.529920	58
33	.838670	.544639	57
34	.829037	.559193	56
35	.819153	.573576	55
36	.809017	.587784	54
37	.798637	.601815	53
38	.788010	.615661	52
39	.777146	.629320	51
40	.766044	.642787	50
41	.754710	.656959	49
42	.743145	.669131	48
43	.731351	.681997	47
44	.719340	.694657	46
45	.707107	.707107	45
	Depart.	Lat.	Deg.
	Even degrees.		

Deg.	One quarter.		One half.		Three quarters.		
	Latitude.	Depart.	Latitude.	Depart.	Latitude.	Depart.	
0	.999997	.004363	.999960	.008727	.999914	.013082	89
1	.999763	.021815	.999658	.026177	.999532	.030538	88
2	.999230	.039260	.999050	.043620	.998848	.047972	87
3	.998399	.056693	.998134	.061048	.997859	.065403	86
4	.997250	.074108	.996916	.078459	.996561	.082808	85
5	.995805	.091508	.995395	.095846	.994968	.100188	84
6	.994056	.108867	.993566	.113204	.993068	.117510	83
7	.992004	.126199	.991445	.130526	.990866	.134852	82
8	.989650	.143493	.989018	.147809	.988360	.152124	81
9	.986998	.160742	.986286	.165048	.985555	.169347	80
10	.984004	.177943	.983255	.182236	.982452	.186524	79
11	.980786	.195091	.979925	.199368	.979045	.203642	78
12	.977231	.212178	.976298	.216439	.975342	.220656	77
13	.973378	.229200	.972371	.233445	.971342	.237680	76
14	.969231	.246152	.968149	.250380	.966971	.254884	75
15	.964789	.263030	.963631	.267239	.962456	.271440	74
16	.960051	.279829	.958820	.284016	.957571	.288196	73
17	.955020	.296542	.953717	.300748	.952393	.304864	72
18	.949700	.313164	.948324	.317304	.946930	.321440	71
19	.944087	.329700	.942649	.333807	.941178	.337917	70
20	.938191	.346117	.936674	.350207	.935135	.354290	69
21	.932009	.362438	.930417	.366501	.928811	.370558	68
22	.925540	.378648	.923879	.382683	.922202	.386711	67
23	.918770	.394744	.917062	.398750	.915313	.402746	66
24	.911763	.410719	.909960	.414693	.908142	.418660	65
25	.904458	.426569	.902585	.430511	.900698	.434445	64
26	.896875	.442289	.894932	.446198	.892978	.450089	63
27	.889016	.457874	.887010	.461749	.884967	.465615	62
28	.880892	.473320	.878818	.477160	.876726	.480988	61
29	.872495	.488621	.870356	.492424	.868196	.496216	60
30	.863836	.503775	.861628	.507538	.859408	.511293	59
31	.854912	.518771	.852641	.522499	.850353	.526213	58
32	.845730	.533615	.843392	.537299	.841037	.540955	57
33	.836287	.548294	.833887	.551937	.831470	.555571	56
34	.826589	.562805	.824107	.566406	.821647	.569996	55
35	.816642	.577145	.814115	.580703	.811572	.584249	54
36	.806444	.591310	.803857	.594832	.801254	.598325	53
37	.796002	.605293	.793355	.608762	.790689	.612218	52
38	.785316	.619086	.782607	.622516	.779884	.625923	51
39	.774393	.632704	.771625	.636079	.768842	.639438	50
40	.763233	.646124	.760407	.649448	.757565	.652758	49
41	.751840	.659345	.748955	.662621	.746057	.665882	48
42	.740219	.672366	.737278	.675591	.734322	.678800	47
43	.728372	.685184	.725373	.688354	.722363	.691513	46
44	.716302	.697790	.713251	.700910	.710185	.703990	45
	Depart.	Lat.	Depart.	Lat.	Depart.	Lat.	Deg.
	three quarters.		one half.		one quarter.		

EXPLANATION.—If the degrees sought are under 45, they stand on the left; but if over 45, they stand on the right of the columns of latitude and departure. The terms "latitude and departure," and the quarter degrees at the top belong to the degrees under 45, found on the left; but the terms "departure and latitude," and the quarters at the bottom belong to the degrees over 45, found on the right; thus: the latitude of 15¼ degrees, is .964789; and its departure .263030, and the departure of 74¾ is .964789, and its latitude .263030.

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EXPLANATIONS AND ILLUSTRATIONS.

It is not pretended that this traverse table presents in all cases, an easier or better method of calculating triangles than is known to mathematicians; but the intention is, to place before those arithmeticians, who have not the opportunity of studying the higher branches of science, the means by which they can avail themselves of the practical use of triangles. It is however believed that for the solution of many problems solvable by the use of this table, that no mathematician knows of a more easy, speedy, or accurate plan of ascertaining the value of lines and angles.

By a little attention on the part of the ingenious arithmetician to the principles here laid down and illustrated, he will acquire much beneficial knowledge of geometry. The problems solved comprehend most of the principles of triangles. There are few cases useful in practice that cannot be wrought out by common decimal fractions, aided by the universal traverse table. It must be especially borne in mind that the latitude and departure given are decimals, and in using them, whether it be to add, subtract, multiply, divide, or reduce, the same rules must be observed in respect to pointing off, &c. as are laid down in the arithmetics for working by common decimals.

Geometricians suppose circles great and small to be divided into 360 equal parts called degrees, and each degree divided into 60 equal parts called minutes. It is evident then that the larger the circle that is thus divided, the longer will the degrees and minutes be. The degree is the one three hundred and sixtieth part of the circumference, let that circumference be long or short. In a circle large enough just to encompass our earth, each degree is 69½ miles long, but in a circle as small as the dotted line in figure 1, the degrees are very short. Geometricians also suppose that the point at which any two straight lines meet, as at A. may be the centre of the circle upon which the degrees between the two lines may be counted. It is perfectly immaterial whether the circle is described in the middle or at the end of the straight lines. In each and every one the degrees between them would be the same in number though not in length. The opening between the lines is called an angle, and the size of the angle is counted in degrees upon the circle. If the number of degrees in an angle be exactly 90 or one quarter of the circle, the angle is called a right angle. A greater angle is called an obtuse angle, a less one acute.

When three straight lines meet so as to enclose a space, that space is called a triangle, because it has three angles or corners as A. B. C. in the figure. If one of those angles be a right angle as at C. the triangle is called a right angled triangle.

Take three staves of equal length, whether that length be one foot, one yard, one pole, or any other length whatever, set one staff upon another as C. B. upon A. C. so as to form a right angle or square at C. Take the other staff A. B. and place it even with the end of A. C. at A. leaning it against the upright one at B. and you have formed a right angled triangle A. B. C. with the right angle at C. Then if previously the staves A. C. and C. B. should have been divided into 10.

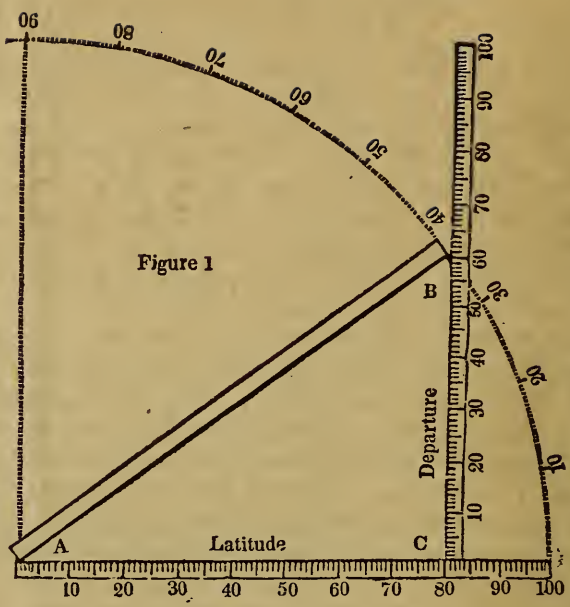


Figure 1

100, 1000, or any number of equal decimal parts, you have scales upon which to reckon the parts of all right angled triangles formed of the same staves. The staff or line A. B. is called one, so is the whole length of each of the staves. The number of parts from A. to C. when forming the triangle is called the latitude, and the number of parts from C. to B. is called the departure of the line A. B. In the table these two staves or any staves or lines so situated, are presumed to be divided into one million of parts each, being the decimal parts of the integer A. B. The angle or opening between the staves A. B. and A. C. as counted on the circle in the figure is 37 degress, accordingly as you will find the latitude and departure opposite to 37 degrees in the tables, you find that C. B stands upon A. C. very nearly at the 80th division, and that A. B. touches C. B. about the 60th division, representing the latitude and departure of A. B. Set the staff C. B. any where upon the line or staff A. C. and lean the line or staff A. B. against it as before, and the intersection at B. will always cut the circle at the degree represented at the sides of the table, while the latitude and departure opposite to the degree in the table, will correspond with the divisions on the lines A. C. and C. B. as marked by the points C. and B.

In all right angled triangles it is known that the two angles at A. and B. added together make just 90 degrees. That as one is increased the other is diminished. In the example before us the angle at B. is 53 degrees, that being the complement of 37 degrees or what 37 degrees lacks of being 90 degrees. Make the angle at A. 25½ degrees and that at B. will be 64½, and so of any number of degrees and parts under 90. In this case A. B. would touch C. B. at .43 + which is the latitude of 64½ and departure of 25½. and C. B. would stand upon A. C. at .90 + the departure of 64½ and the latitude of 25½ as shown in the table. It is thus that the latitude of all angles under 45 degrees is the departure of all angles over 45 degrees, of which such angles are the complements. Hence one half of the figures and size of a traverse table is saved by reversing the terms latitude and departure at top and bottom as applied to angles under and over 45 degrees.

It is known that as long as the angle at A. remains the same, whether it be 37 or any other number of degrees, or degrees and parts, that the other parts of the triangle will bear the same proportion to the line

or unit A. B., let the triangle be enlarged or diminished ever so much. Thus if A. B. is made 3, 4, 20, or any number of times as long as that in the figure, the latitude and departure or the lengths A. C. and C. B. will be 3, 4, 20, or any other [the same] number of times the lengths that they are in the figure.

In using the table, unless great accuracy is required, or the lines very long, it is unnecessary to use more than three, four or five of the figures. The table is carried so far into decimal parts that if A. B. were one mile long, one in the table would be about one sixteenth of an inch. There may be as many rejected from the right hand as the nature of the case will admit, taking care to increase your right hand figure one, if the left one, you reject be 5 or over. Thus the departure of 31 degrees might be set down .515—that of 37 degrees .602 and that of 32 degrees .530 or .53. Should you wish to know the latitude and departure answering to any number of minutes less than 15 or a quarter of a degree, take out the latitude for the quarter next greater, and next less than the deg. and minutes sought. Subtract the less from the greater latitude; multiply the difference by the number of odd minutes, divide the product by 15 and subtract the quotient from the greater latitude taken out, and the remainder is the latitude sought For finding the departure the process is the same, except the quotient found is to be added to the less departure taken out; the sum is the departure of the degree and minutes.

What is the latitude and departure of 42 degrees and 17 minutes? 17 minutes being one quarter and two minutes, lat. 42¼ .740219 less by lat. of 42½ .737278 = 3021 × 2 and divided by 15 = 403. .740219 —403 = 739816 the lat. of 42 degrees and 17 minutes. Again dep. of 42½ .675591 — dep. of 42¼ .672366 = 3225 × 2 and divided by 15 = 430. .672366 + 430 = .672796 the departure of 42 degrees and 17 minutes.

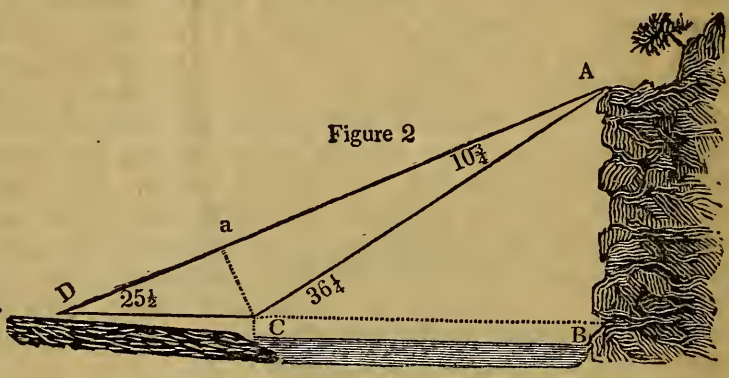
APPLICATION.

What is the rise of 10 feet at 3 degrees of elevation? Dep. of 3 deg. = .052336 × 10 = .52336 feet × 12 = 6.28032 inches, that is 6 inches and a little over a quarter, answer. I find a plane descends 7 inches in 33 feet, what is the degree of descent? Divide 7 inches by 12 gives .583333 of a foot. Divide this by 33 feet gives .017676 being the departure of one foot at the rate of 7 inches in 33 feet. In the table is found that the departure of 1 foot at 1 degree is 017451 so that one degree is the descent of the plane very nearly. I find from the centre to the eave of a house is 17 feet and that the face of the roof from eave to comb is 21 feet, what degree of slope has the roof? Divide 17 feet which is A. C. in fig. 1 by 21 which is A. B. and you have .809524 as the proportional latitude and by searching the table for the nearest latitude you find that the slope of the roof to be a little less than 36 degrees. From the centre of a house to the eaves on each side is 20 feet. It is desirable to pitch the roof 40 degrees; how high must the comb be raised above the square and how much will the roof face on each side? As .766 latitude of 40 deg. is to .643 dep. so 20 ft. is to 16.78 ft rise answer. 20 feet divided by lat. of 40 deg. .642787 = 26.1 feet answer face of roof or A. B. in fig. 1.

There is a church with a spire erected over its centre, my eye is 480 feet from the centre of the church and level with the floor; I find the elevation of the spire to be 20 degrees, query its height above the floor, and its distance from my eye? As .9397 the lat. of 20 deg. is to .342 the dep. of 20 deg. so 480 feet is to 174.7 feet height of spire. Divide 480 feet by .9397 lat. of 20 deg. gives 510.8 feet the distance of the spire from my eye or A. B. of the figure. I change my position on level ground and now find the spire elevated 23½ degrees, what is my present distance from the centre of the church? As dep. of 23½ deg. .3987 is to lat. of 23½ degrees .917, so 174.7 feet is to 401.8 feet, my present distance from the centre of the church.

There is an inaccessible cliff, A. B. figure 2. which rises perpendicularly from the side of a river. From the opposite shore, at C. the top of the cliff is elevated 36¼ degrees from my eye, which is ten feet above the water. I recede from the shore on level ground 72 feet, and find the top of the cliff elevated from this station, at D., 25½ degrees: What is the distance of my eye at each station from the top of the cliff, also the perpendicular height of the cliff above the water and the breadth of the stream, C. B.? 36¼ — 25½ = 10¾ degrees, the angle D. A. C.; for as one of the acute angles of a right-angled triangle is diminished the other is increased, as before stated: D. A. B. and C. A. B., being rightangled triangles, having the common perpendicular A. B.

Figure 2



72 × .430511, the dep. of 25½ = 30.996792 = C. a.

72 × .902589, the lat. of 25½ = 64.98612 = D. a.

As .186542, dep. of 10¾ degs. is to .982452, lat. of 10¾ degs: so 30. .996792. = C. a. is to 163.2651 feet = A. a. A. a. 163.265 + D. a. 64.986 = D. A. 228.251; which is the distance from the 2d station D. to top of precipice A.

C. a. 30.996792 divided by .186524 dep. of 10¾ degs. = 166.181 feet C. A.; the distance from 1st station C. to top of cliff. Line D. A. 228.251 × .430511 dep. of 25½ degs. = 98.2645 feet; the height of the cliff above the level of the eye; add 10 = 108.264 feet, the height of the top of cliff from water.

Line C. A. 166.181 × .591310 dep. of 36¼ degs. = 98.264 feet; the height of top of cliff above the level of the eye at 1st station, add 10 feet the height of eye above water, gives 108.264 feet, the height of cliff; the same as before.

166.181 C. A. × .806444 lat. of 36¼ = 134.016 feet, width of the stream.

228.251 D. A × .902585 lat. of 25½ = 206.016, from which take 72

feet, distance between stations, = 134.016 feet, the width of stream, and same as before.

By the same principles of solution, horizontal angles, taken with a compass, may be wrought as well as most if not all the most beneficial and practical values of right lines and angles may be determined without recourse to trigonometry.

The mechanical power of inclined planes is inversely proportional to their departures very nearly, if the inclination be not great. At 8 degrees of inclination, the error amounts to less than .01 of the power. At 25 degrees, it amounts to less than .1 of the power, being equal to the excess of 1. over the latitude of the plane.

What is the angle at the point of a wedge, the power of which will be 25 fold, that is to raise 25 pounds for every pound of power applied over and above the resistance of friction? 1. divided by 25.=.04; which is a little more than the departure of 2¼ degrees—which is the answer, very nearly.

I find the thread of a screw forms an angle of three degrees with a rule laid perpendicular to or directly across the spindle,—what is its power? 1. divided by .052336, the dep. of 3 degrees, = 19 fold; which is the power of the screw.

It is found, that the power necessary to move a common wagon on a level smooth road, is equal to $\frac{1}{29}$th of its weight. At what degree of inclination must such a road he made, so that a wagon will just stand or run upon it, that is, upon which the inclination of the wagon to descend will just equal the friction? 1. divided by 29 = .034483; which is the dep. of 2 degrees very nearly, or the inclination of road required.

What portion of the weight of a carriage and load pushes against the wheel horses in descending such a road at 4½ degrees of inclination, with the wheels unlocked? .078459 dep. of 4½ degs., lessened by the departure to balance friction above .034483 = .043976. 1. divided by this sum gives 22.7, nearly; or about 1 pound for every 22.7 pounds of weight; or ninety nine pounds to the ton of wagon and load, nearly.

What is the force required to draw carriages up the same plane? .078459 dep. of 4½ degs. increased by the above sum .034483 for friction, gives .112942. 1. divided by this sum gives 8.8: that is, one pound of force for each 8.8 pounds of wagon and load; or about 255 pounds to the ton of wagon and load.

I find that $\frac{1}{7}$th of the weight of a horse applied at right angles to the arms of a tread-wheel, will produce the requisite power: What inclination must be given to the wheel, so that the horse walking upon it will give the necessary power? 1. divided by 7. gives .142857, or a trifle less than the departure of 8¼ degrees, which is the inclination required.

A COMPREHENSIVE REDUCTION TABLE.

LONG MEASURE.

	Inches.	Feet.	Yards.	Poles.	Chains.	Miles.
1 league is	190,080.	15,840.	5,280.	960.	240.	3.
1 miie is	63,360.	5,280.	1,760.	320.	80.	1.
1 chain is	792.	66.	22.	4.	1.	.125
1 pole is	198.	16.5	5.5	1.	.25	.003125
1 yard is	36.	3.	1.	.181818+	.045455—	.000568+
1 foot is	12.	1.	.0333+	.060606+	.015152—	.000189+
1 inch is	1.	.083+	.0277+	.005051—	.001263—	.000016—

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